AD 718561

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Materiel Test Procedure 5-2-533
White Sands Missile Range

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

3923

MISSILEBORNE COMPUTER (MECHANICAL)

1. OBJECTIVE

The objective of this test procedure is to ascertain pertinent characteristics such as accuracy and repeatability of missileborne computers.

2. BACKGROUND

Because of missile accuracy and weight restrictions,most mathematical operations are performed by electro-mechanical or electronic components. The most common mechanical computer element is the ball and disk integrator coupled to a differential. This component is used in inertially guided missiles to integrate acceleration signals to give velocity and velocity inputs to compute displacement. The operation of the ball and disk integrator is discussed in detail in Appendix A.

3. REQUIRED EQUIPMENT

a. AC power supply (3 required)
b. AC volt meter
c. Calibrated dial
d. Double-pole, double-throw switch
e. Double-pole, single-throw switch
f. Electric timer
g. Induction motor
h. Microswitch(2 required)
i. Relay
j. Relay power supply
k. Synchronous motor
l. Timer power supply
m. Variable transformer

4. REFERENCES

A. ASA Z32.13-1950, Abbreviations for Use On Drawings, American Standards Association, New York, New York, 1950.
B. Soroka, Walter W., Analog Methods in Computation and Simulation, McGraw-Hill Book Company, Inc., New York, New York, 1954.
C. Svoboda, Antonia, Computing Mechanisms and Linkages, McGraw-Hill Book Company, Inc., New York, New York, 1948.

5. SCOPE

5.1 SUMMARY

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This MTP describes the following tests

a. Gear Train Friction and Direction of Rotation Test - A test to measure the torque required to overcome gear friction and to check for proper direction of rotation.

b. Integrator Zero and Backlash Test - A test to determine that the differential output at any established zero position does not exceed the specified tolerances.

c. Integrator Accuracy Test - A test to measure the differential output as an angular velocity

d. Carriage Excursion Time Test - A test to determine the ball carriage maximum excursion time

5.2 LIMITATIONS

The tests in this MTP pertain to mechanical computers of the ball and disk integrator type only.

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Testing personnel shall be familiar with the mechanical computer they are to test and qualified to operate the test equipment they are to use.

b. Prior to the test, all pertinent technical manuals, manufacturer's specifications/drawings, etc., shall be reviewed to permit a proper selection of test equipment and accessories.

NOTE: The test and monitoring equipment shall have an accuracy potential of at least five times that of the unit being tested.

NOTE: Suitable protection from high voltage shall be provided.

c. Ascertain that the computer physical characteristics are in accordance with specified weight and measurements.

d. Visually inspect the computer for physical damage or corrosion.

e. Assure that all power switches are in the off position.

f. Assure that the variable transformer is adjusted for minimum electrical coupling

6.2 TEST CONDUCT

6.1 GEAR TRAIN FRICTION AND DIRECTION OF ROTATION TEST

a. Mount the unit under test in a suitable fixture and connect the equipment as shown in Figure 1.

b. Apply power to the induction motor and synchronous motor, thus increasing the voltage, in small increments from zero until the motor starts and rotates at the slowest continuous speed, with minimum noise and vibration.

d. Record voltmeter reading.
e. Check that induction motor and dial rotate clockwise (CW).
f. Reverse the phase to the induction motor by throwing DPDT switch to the other position.
g. Check induction motor and dial for couterclock-wise (CCW) rotation.

6.2.2 Integrator Zero and Backlash Test

a. Apply power to the snychronous motor to rotate the disk of the integrator at a constant angular velocity.
b. Position the ball carriage to the zero position by approaching the setting from the center of the disk radius and record the dial indication of the differential output.
c. Repeat step b, four times and record differential output readings.

6.2.3 Integrator Accuracy Test

a. Decouple the ball carriage drive system.
b. With the synchronous motor turning the disk, manually position the ball carriage at ten (10) discreet increments, 5 on each side of disk centers.
c. Record the respective dial indications at the differential output shaft for each increment.
d. Repeat step b and c, with the ball carriage in the opposite direction and record differential output.

6.2.4 Total Carriage Excursion Time Test

a. Mount the unit under test in a suitable fixture and connect the equipment as shown in Figure 2.
b. Apply power to the disk drive system and position the carriage shaft to the maximum left excursion.
c. Position the No. 1 microswitch actuating arm against the shaft so that the switch is open and so that the slightest lateral movement of the shaft will close the switch, and thus close the relay coil circuit, secure the switch in this position.
d. Manually move the carriage shaft to the zero position.
e. Position the No. 2 microswitch actuating arm against the other end of the shaft end so that the microswitch barely opens.
f. Reposition the carriage shaft to the maximum left excursion position.
g. Apply power (90° phase) to the carriage drive system and record the elapsed time for one lateral movement of the carriage.
h. Repeat steps a through g, a minimum of three times.
i. Determine the reverse carriage excursion by revising the microswitch interconnections to permit an interchange of their functions.

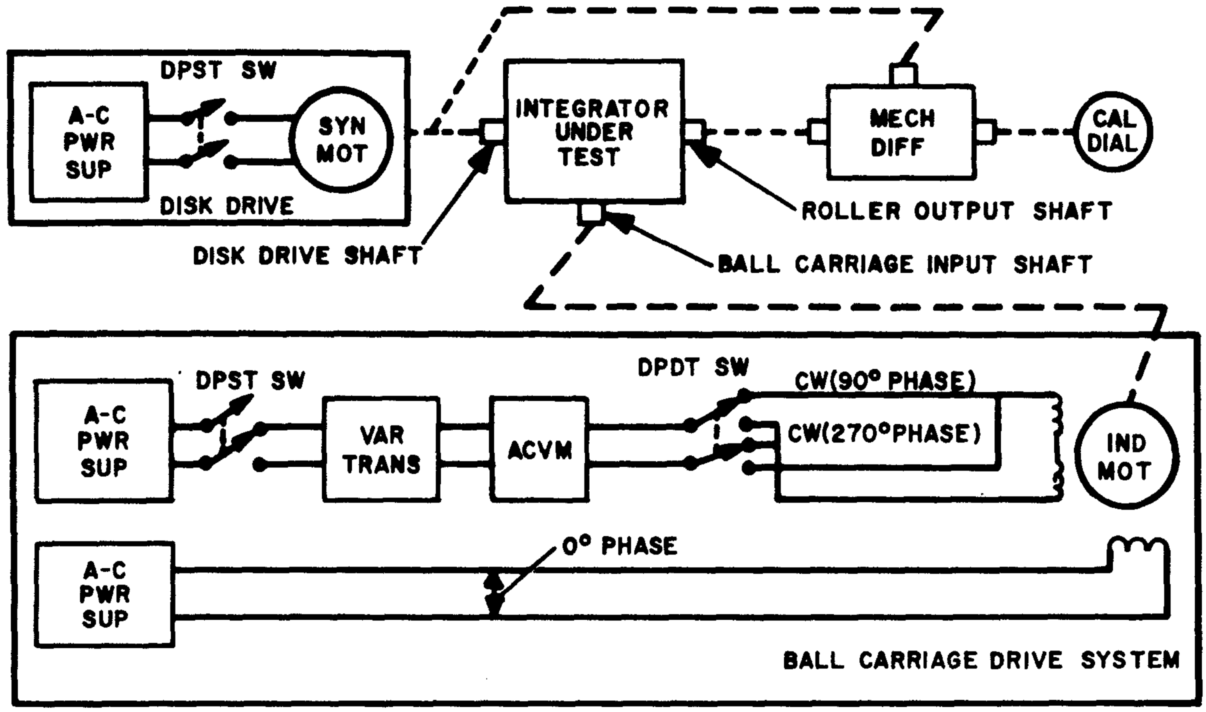


Figure 1. Test Configuration for Gear Train Friction, Direction of Rotation, Zero, Backlash, and Accuracy Tests of Mechanical Computer

6.3. TEST DATA

6.3.1 Gear Train Friction and Direction of Rotation Test

Record voltmeter readings.

6.3.2 Integrator Zero and Backlash Test

Record differential output readings for steps b and c.

6.3.3 Integrator Accuracy Test

Record the respective dial indications at the differential output for each increment for steps c and d.

6.3.4 Total Time Excursion Time Test

Record the elapsed time for one laterial movement of the carriage.

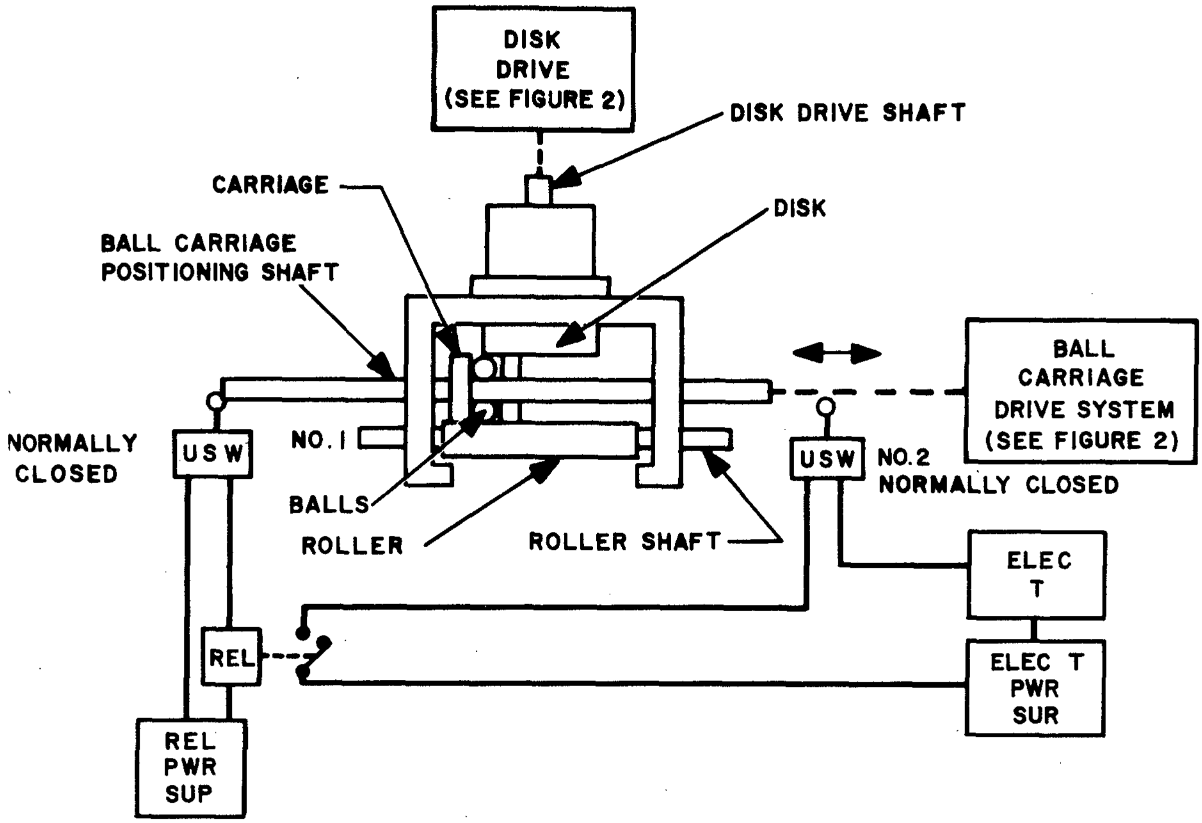


Figure 2. Test Configuration for Ball Carriage Excursion Time Test

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Gear Train Friction and Direction of Rotation of Test

Determine if the torque, measured in terms of voltage exceeds the specified tolerance.

6.4.2 Integrator Accuracy Test

Compute standard deviation for 10 readings taken in this test and compare with specified tolerance, taking into consideration error contribution of the differential if specification is only for ball and disk integrator.

6.4.3 Total Carriage Excursion Time Test

Determine the reverse carriage excursion by revising the microswitch interconnections to permit an interchange of their functions.

APPENDIX A

The tests in this document include certain mechanical and electro-mechanical devices required to furnish inputs and provide output coupling to the integrator under test. Although this equipment is only required to form a part of the test configuration, a brief operational description of the equipment and integrator follows.

As shown in Figure A-3, the ball of the ball and disk integrator is turned by contacting a disk which is rotating at a constant rate with respect to time. The contact point between the disk and ball can vary in position from center to the circumference of the disk. The contact position is dependent upon and is dictated by the error signal, which is applied to the electro-mechanical system employed to position the ball carriage. When the error signal is zero the ball remains at the center of the disk and does not turn. When outer edge of the disk the ball turns increasingly faster. The revolutions executed by the ball and output roller, are proportional to the integral of the error signal with respect to time. Mathematical derivations and expressions of these relations are shown in Figure A-3.

An induction drive motor is used to drive the ball carriage of the integrator. Amplitude control and phase reversal of the motor can be accomplished so that speed and direction of rotation can be controlled. The input to the motor is monitored and the reading obtained is used as a measurement of input signal to the integrator.

A calibrated dial is attached to the differential gear train, or displacement shaft, for purposes of direct visual indications of the velocity or displacement shaft position. The scale factor and divisions on the dial are selected to determine the shaft position to a degree of accuracy compatible with requirements.

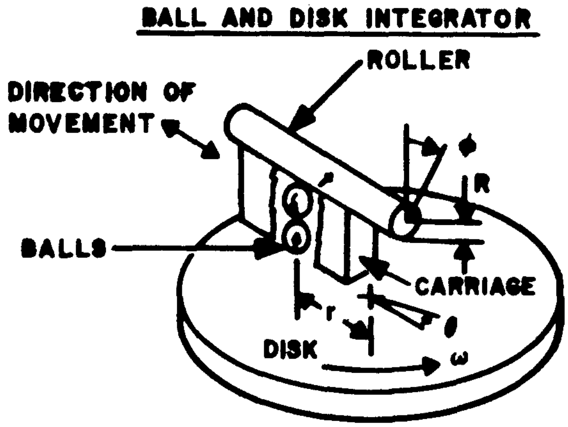
A synchronous drive motor is used to drive the disk of the ball and disk integrator, one input to the mechanical differential, and the measuring potentiometer. The differential is employed to couple the output of the ball and disk integrator and the synchro-drive motor to the ultimate displacement channel. The integrator and drive motor shaft displacement will be summed by the differential. The scale factor for each input will be dictated by the integrator. The output scale factor is fixed by the input scale factor of the displacement module.

ϕ – ROLLER SHAFT OUTPUT
R – RADIUS OF ROLLER
r – RADICAL DISTANCE FROM DISK CENTER
θ – ANGULAR DISPLACEMENT OF DISK
w – ANGULAR VELOCITY OF DESK

GIVEN: $w = \frac{d\theta}{dt}$ or $d\theta = w\,dt$

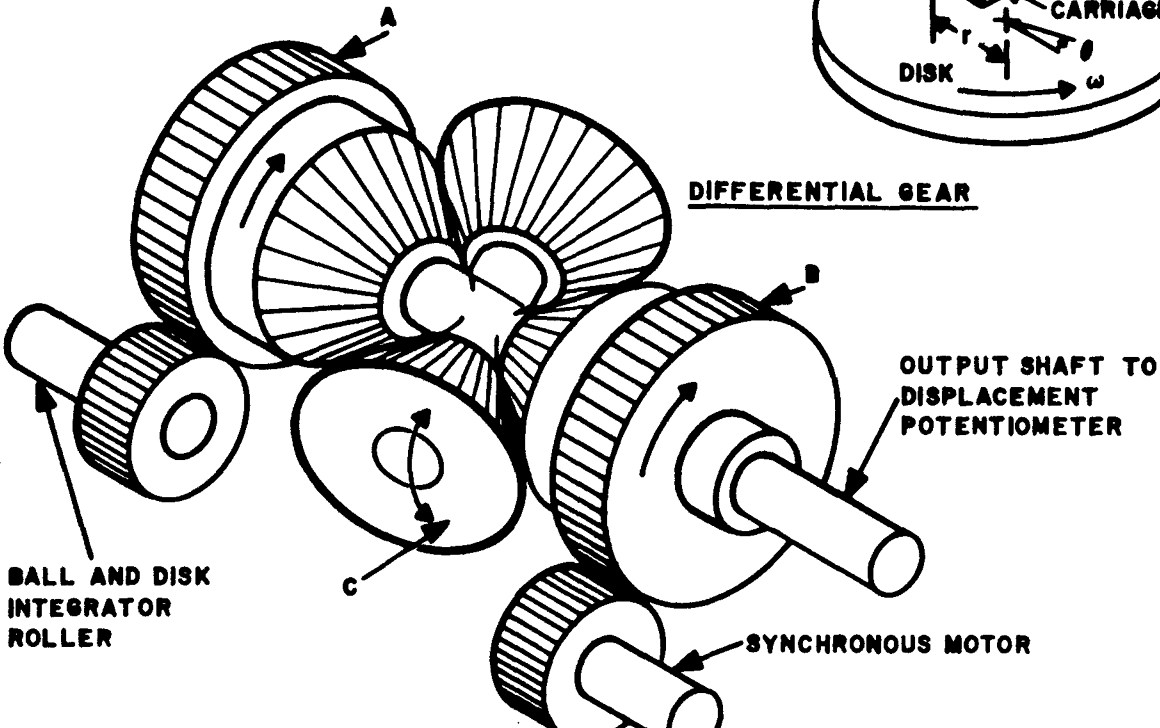
$R\,d\phi = r\,d\theta$ AND $R\,d\phi = r\,w\,dt$

$d\phi = \frac{w}{R} r\,dt$



INTEGRATING:

$\phi = \frac{w}{R}\int r\,dt + K$



$C = \frac{A+B}{2}$

Figure 1. Ball and Disk Integrator, Differentail Gear, and Respective Mathematical Derivations.